

## NOTES

### A LARGE, OPENING-CLOSING MIDWATER TRAWL FOR SAMPLING OCEANIC NEKTON, AND COMPARISON OF CATCHES WITH AN ISAACS-KIDD MIDWATER TRAWL

Avoidance of nets by agile micronekton and nekton is one of the major problems with small midwater trawls routinely used for oceanic sampling by oceanographers and marine biologists (e.g., Harrison 1967; Pearcy 1975; Roper 1977). A major advantage of small trawls is that they can be equipped with opening-closing devices so that samples can be ascribed to discrete depths. This capability is especially important for sampling deep water where densities of animals are low. An opening-closing rectangular midwater trawl with a mouth area of about 25 m<sup>2</sup> is the largest opening-closing net described (Baker et al. 1973). Another important advantage of small nets is that they can be used from most oceanographic vessels.

Large, commercial-size midwater trawls used to sample oceanic micronekton (Berry and Perkins 1966; Harrison 1967; Taylor 1968; Clarke 1973, 1974; Krefft 1974; Roper 1977) are usually not evaded as successfully by nektonic animals. Big nets which filter large volumes of water have the added advantage of catching enough animals to characterize species and size composition from sparsely populated waters. However, these large nets lack opening-closing capability, and most oceanographic research vessels are unable to handle large nets, otter doors, and bridles (Pearcy 1975).

This paper describes a 50 m<sup>2</sup> pelagic trawl especially designed for use with an opening-closing cod end, attempts to evaluate its performance, and compares its catches of mesopelagic fishes and cephalopods with those from a 5.4 m<sup>2</sup> Isaacs-Kidd midwater trawl.

#### Midwater Trawl Description and Operation

The midwater or pelagic trawl was designed by G. Loverich, Nor'Eastern Trawl Systems, Inc.,<sup>1</sup> Bainbridge Island, Wash., for sampling meso-

pelagic fishes and cephalopods in conjunction with a 1 m<sup>2</sup> five-net opening-closing device which is attached to the cod end of the trawl (Figure 1). The body of the trawl is lined throughout with 19 mm (¾ in) stretch mesh. The net is 42 m long and was constructed with a gradual taper from mouth to cod end in order to provide a large netting area for filtration in order to reduce the water velocity through the meshes, stagnation and hang-up of animals on the netting, and extrusion of animals through the netting. The wings of the trawl are made of large mesh (292 mm). It was assumed that micronekton (fishes, squids, and shrimps up to 200 mm in length) escape or pass through this large mesh rather than lead into the trawl body, giving an effective diameter of the net for micronekton equivalent to the small mesh body of the trawl. Unfortunately data do not exist to evaluate herding or leading of oceanic micronekton by the wings of trawls.

The trawl has six seams with four identical panels for the top and bottom (wing, body, and intermediate) two identical side (wing, body, and intermediate) panels, and four cod end panels (Figure 2). The meshes were hung at 29.3% in both directions to allow formation of square openings and laced to make six seamlines. Two riblines are located along the middle of the side panels and extend to the opening-closing device.

A 1 m<sup>2</sup> Multiple Plankton Sampler (MPS) with five separate nets, each 4.6 m long (see Pearcy et al. 1977 for details), was used as an opening-closing cod end device on the trawl. The levers for release of the five nets of the sampler are actuated by a modular timer which employed a crystal oscillator and a binary series of counters for selection of release times (Evans 1975). The timer is mounted on the MPS, started as the trawl is launched, and is set to give the trawl time to stabilize at a selected towing depth before net 1 is released (usually 30-60 min). Thus the first net fishes obliquely from the surface to the fishing depth of net 2. The four remaining nets (nets 2-5) all fish the same amount of time on a given tow (usually 40 min), either at the same depth (horizontal series) or at different depths (vertically stratified series).

The footrope and headrope are each 28.6 m of 16

<sup>1</sup>Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

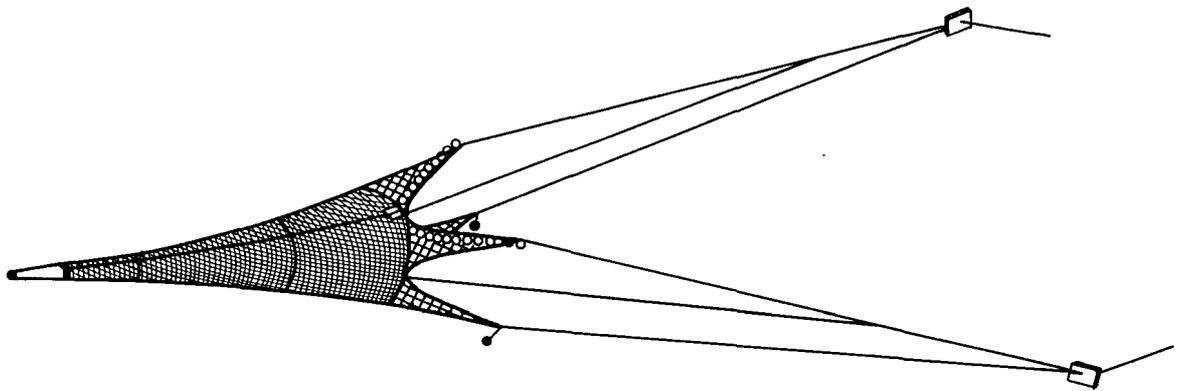


FIGURE 1.—Sketch of the pelagic trawl in operation.

mm poly-Dacron rope. The wings are of #60 thread, the body of #3 thread, the intermediate of #4 thread, and the cod end of #6 thread. Nineteen 25.4 cm (diameter) aluminum floats (good to 1,000 m) are attached to the headrope. Galvanized chain is attached to the footrope and one 23 kg lead ball is attached to the tip of each of the bottom wings. The bridles to the bottom wings are 55 m long; bridles to the upper wing are 36 m long, and the middle bridle is 47 m long (Figure 1).

The trawl was designed to be towed with 1.5-1.8  $\times$  2.4-2.7 m (5  $\times$  8 ft or 6  $\times$  9 ft) otter doors. A scale model of the trawl was first constructed and tested in a tank to test its design and performance.

Observations were made on the trawl by divers during trials in Puget Sound using 1.8  $\times$  2.7 m doors and towing speeds of 1.0 to 1.6 m/s at depths of about 12 m. The towing characteristics of the net were observed and the number of floats needed to provide neutral buoyancy to the cod end opening-closing device was determined by trial. At a towing speed of 1.6 m/s the vertical opening of the mouth was measured to be about 8 m and the body of the trawl was observed to be nearly circular and about 8 m in diameter, providing an estimate of about 50 m<sup>2</sup> for the cross-sectional area of the fine mesh netting of the trawl body.

The depth that each net fished was determined from the depth-modulated signal from an acoustical pinger mounted on the headrope of the trawl, a hydrophone towed from the vessel, and a graphic recorder. An EG&G pinger was used initially but was replaced with an Institute of Oceanographic Sciences (IOS) 0-683 m (0-100 atmospheres pressure) acoustical net monitoring system (Baker et al. 1973) with an overall accuracy of 0.1% of the full depth range.

## Methods

A timer-actuated ejection device was used as a method to provide some information on the flushing rate through the body of the trawl. This device, similar to the one described by Percy et al. (1977), has a modular timer (Evans 1975) to release the contents of two 1.3 l chambers. It was hung from the headrope inside the trawl mouth and its contents were ejected against the 19 mm mesh. Preserved juvenile salmon (10-20 cm total length) were released into the net at intervals of 5, 10, 15, or 25 min before closure of net 1 and opening of net 2.

The pelagic trawl-MPS combination was used on three chartered trawlers off Oregon. All vessels had net reels and used double-warp towing. A boom was used to launch and recover the MPS during 1975 and 1976 cruises. The vessel chartered in 1977 had a stern ramp, which greatly facilitated use of the pelagic trawl. Twelve tows were made in 1975 to test the monitoring equipment and to evaluate flushing of the net. Eight tows were made in 1976 and 10 in 1977. All tows were 110-130 km off the central Oregon coast; 18 of these tows provided the data for comparison of pelagic trawls and Isaacs-Kidd midwater trawls (IKMT's) (Table 1).

Tows were also made with a 5.4 m<sup>2</sup> IKMT with 10 mm stretch mesh and a 1 m<sup>2</sup> MPS opening-closing device (Percy et al. 1977) at 1.5-2.0 m/s at a similar location and within 10 days after each of three cruises that used the pelagic trawl (Table 1). Volume of water entering the IKMT was monitored with a modified TSK flowmeter on all tows. One of the purposes of these IKMT tows was to enable comparisons of the catches by the two different types of nets.

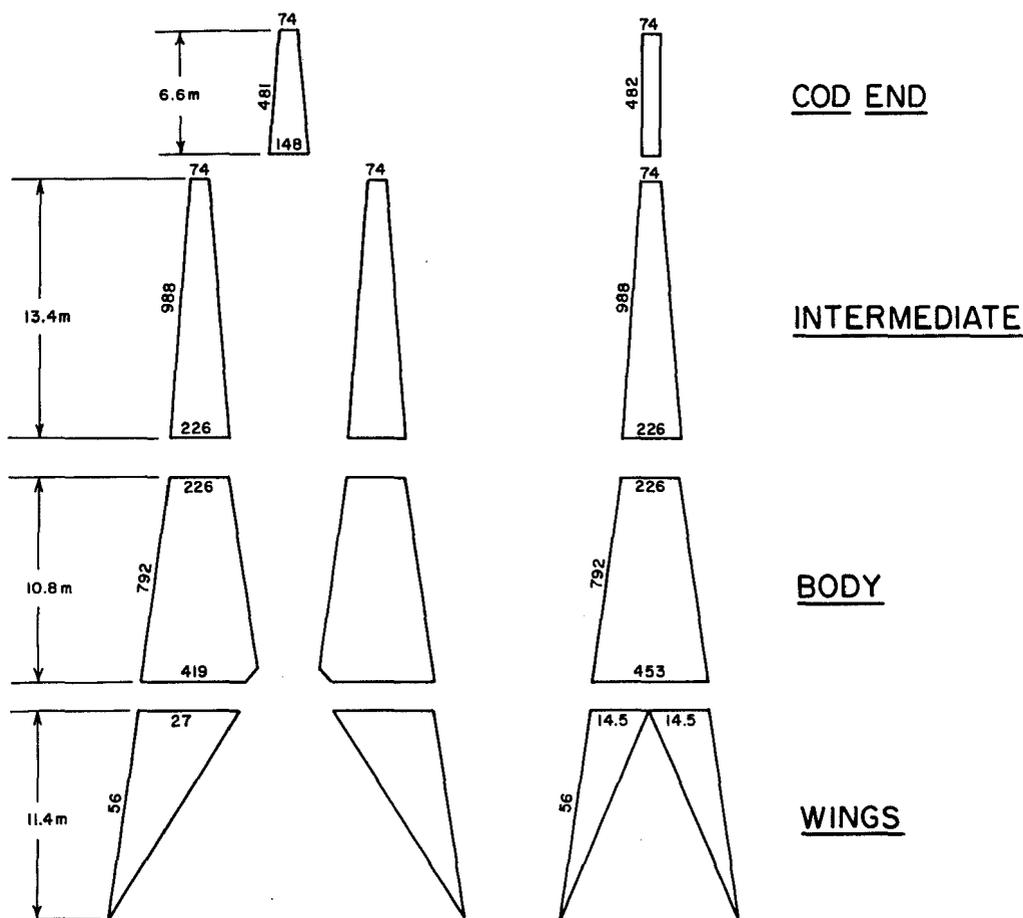


FIGURE 2.—Net plans for the pelagic trawl. Numbers on the net panels indicate number of meshes along the margins.

Collections were preserved in 10% Formalin at sea. In several instances large catches (>35 l) of the pelagic trawl were subsampled, but at least 14 l of the catch of each of the nets for discrete depths were preserved. Fishes and cephalopods were identified and measured [standard length (SL) of fishes and dorsal mantle length (DML) of squids].

TABLE 1.—Summary of pelagic trawl (PT) and Isaacs-Kidd midwater trawl (IKMT) tows made on the three "paired" cruises off Oregon.

Net	Dates	Vessel	No. Tows	Depth (m)	Time
PT	1975: 23 Sept.	<i>Betty-A</i>	1	340-360	Day
IKMT	12-16 Sept.	<i>Yaquina</i>	5	334-362	Day
PT	1976: 19-22 July	<i>Pacific Raider</i>	8	0-500	Day-night
IKMT	8-13 July	<i>Wecoma</i>	11	0-465	Day-night
PT	1977: 30 July-2 Aug.	<i>Excalibur</i>	9	185-365	Day-night
IKMT	8-10 Aug.	<i>Wecoma</i>	5	187-350	Day-night

## Results

### Flushing of the Pelagic Trawl

In Puget Sound, divers observed that dead salmon smolts released in the mouth of the trawl were never stuck against the netting in the forward part of the trawl where the meshes were taut from water pressure. Occasionally fish stalled against the mesh in the aft section of net where netting was less rigid, but these fish were easily dislodged and tumbled toward the cod end. Because live fishes usually swim away from the netting when inside a trawl, it seems unlikely that live, active fish would be pinned against the netting (G. Loverich<sup>2</sup>). Obviously, dead, preserved fish do not

<sup>2</sup>G. Loverich, Nor'Eastern Trawl Systems, Inc., Bainbridge Island, WA 98110, pers. commun. January 1979.

behave like live ones, but they do provide some information on flow characteristics through the net and how easily objects are pinned against the mesh.

The results of the release of preserved salmon smolts into the mouth of the pelagic trawl on two cruises in the open ocean are shown in Table 2. Ninety-seven percent of the fish released in the mouth were recovered in cod end nets 1 and 2 within 5-25 min after release: 82% were recovered in net 1. These data indicate an average residence time of preserved fish of <10 min in the body of the trawl.

If live animals were delayed by 10-120 min in passing through the net into the cod end, then the number of animals found in different cod end nets may vary, with largest numbers in latter nets and fewest in the first or second net as found by Foxton (1970) and Donaldson (1975) in other cod end opening-closing devices. Coefficients of concordance,  $W$ , (Tate and Clelland 1957) were not significant ( $P > 0.2$ ) for rank order of abundance of fishes (12 tows), squids (10 tows), and *Stenobrachius leucopsarus*, the most common fish (10 tows) for nets 2-5 that sampled equal time intervals and also caught at least 10 of each of these three types of animals. Similar nonparametric tests of the rank order of abundance of 15 common species were not significant for nets 2-5 of nine tows with same net, where each net fished 2 h (Willis 1979). This lack of correlation of catch with net number provides no evidence for delay or stagnation of animals in the net over time periods of 10 min to 6 h. Characteristic species compositions or size-frequency distributions from specific depths (Willis and Pearcy<sup>3</sup>) also indicate that cod end catches are predominantly from the depths fished.

Entanglement or hang-up of fishes and cephalopods in the meshes of the trawl appeared to be restricted to a few types. Fishes such as the stomiatoid, *Tactostoma macropus*, were occasionally found hanging on the meshes of the trawl body by their teeth. Soft-bodied cephalopods, such as *Chiroteuthis calyx* and *Vampyroteuthis infernalis*, were sometimes entangled in the mesh. The number of animals hung on the net after a tow was always a small fraction of those in the cod ends. These entangled animals that are retained in the net from one tow are probably washed-down

TABLE 2.—Results of release of preserved salmon from the ejection device in front of the pelagic trawl. All tows were horizontal at 2.5-3.0 kn. ND means no data.

Vessel	Minutes that ejection device was set to go off before closure of net 1	Interval between closure of nets 2-5 (min)	No. of fish in net:					No. recovered/no. used
			1	2	3	4	5	
<i>Betty-A</i>	10	15	35	0	0	( <sup>1</sup> )	( <sup>1</sup> )	ND
	10	15	35	0	0	0	( <sup>1</sup> )	ND
	10	15	30	3	0	0	0	ND
	25	20	36	0	0	0	0	ND
<i>Pacific Raider</i>	5	40	30	24	1	4	2	61/65
	10	40	20	23	22	20	27	43/60
	10	40	33	25	0	0	0	58/60
	15	40	49	1	0	0	2	52/59
Percent recovered in each net			82	15	1	1	1	

<sup>1</sup> Net failed to close.

<sup>2</sup> Cod end of trawl was twisted. This trawl was excluded from percentage calculations.

into the first net of the next trawl. Since this first net is the one that fishes obliquely from the surface to the selected depth of sampling, it is not usually used in studying vertical distribution of animals.

#### Pelagic Trawl-IKMT Comparisons

The 17 pelagic trawls caught almost twice as many species of fishes, and about the same number of cephalopod species as the 16 IKMT's during the two major cruises in 1976 and 1977. These differences are mainly due to the large volumes of water filtered by the pelagic trawl and consequently the large number of individuals captured.

One of the most significant differences between the catches was the presence of some fish species in the pelagic trawl and their complete absence in the IKMT catches (number caught-vessel, where PR = *Pacific Raider* and EX = *Excalibur*): *Aphanophus carbo* (3-PR), *Merluccius productus* (3-PR), *Idiacanthus antrostomus* (23-PR), *Aristostomias scintillans* (24-PR, 6-EX), *Macrouridae* (5-PR), *Lestidium ringens* (37-EX), *Nansenia candida* (22-EX), *Symbolophorus californiensis* (5-EX). In over 2,000 (2, 2.5, and 3 m mouth opening) IKMT tows made off Oregon since 1961, we have never before captured *Aphanophus carbo* or *M. productus* in oceanic waters. These fishes were large (436-570 mm) and presumably always avoid IKMT's.

#### Length-Frequency Comparisons

Significant differences [ $P < 0.5$ , Kolmogorov-Smirnov (K-S) two sample comparisons (Tate and Clelland 1957)] were found in the size-frequency

<sup>3</sup> Willis, J. M., and W. G. Pearcy. Spatial and temporal variation in the population size structure of three lanternfishes (Myctophidae) off Oregon. Unpubl. manuscr.

distributions of four common species (where  $n > 50$  for fishes for each of the two nets, and  $n > 20$  for squid) for: *Stenobranchius leucopsarus* in two of the three comparisons, *Diaphus theta* in one of two comparisons, and *Tarletonbeania crenularis* in two of two comparisons. In all instances where length distributions differed, the pelagic trawl caught an appreciably higher percentage of large animals. Even though the one K-S test for the squid *Gonatus pyros* was not significant (because of small numbers caught in the IKMT), 15% of numbers of this squid from the pelagic trawl were  $> 35$  mm DML and no animals  $> 35$  mm were caught in the IKMT.

Length-frequency distributions for *S. leucopsarus* and *T. crenularis* from both trawls (Figure 3) show that large lanternfishes are clearly undersampled by the IKMT. The modes composed of fishes  $> 45$  mm, which are prominent in pelagic trawl catches, are absent in IKMT catches.

Another notable example of differences between catches of large fish in these collections were captures of *Tactostoma macropus*. Few large individuals ( $> 250$  mm) have been collected in IKMT tows off Oregon. Three tows with the pelagic trawl at depths of 470-1,070 m in 1978, however, captured many large fish. Twenty-nine percent of the *T. macropus* caught in these pelagic trawl collections were  $> 250$  mm, compared with only 8.2% in 252 IKMT tows to 500 m depth or deeper during previous years.

#### Effective Cross-Sectional Area of the Pelagic Trawl

The cross-sectional area of the pelagic trawl was indirectly estimated from the catches of four species of lanternfishes caught in both the pelagic trawl and IKMT on the three "paired" cruises (Table 1) to see how it compared with the divers' estimates of 50 m<sup>2</sup>. The following equation was used:

$$A = \frac{C_1 V}{C_2 D}$$

where A = area in square meters,  
 $C_1$  = number of fish caught by pelagic trawl,  
 V = volume filtered by the IKMT, in cubic meters,  
 $C_2$  = number of fish caught by the IKMT,  
 D = distance trawled by the pelagic trawl in meters.

The volume of water filtered by the IKMT was

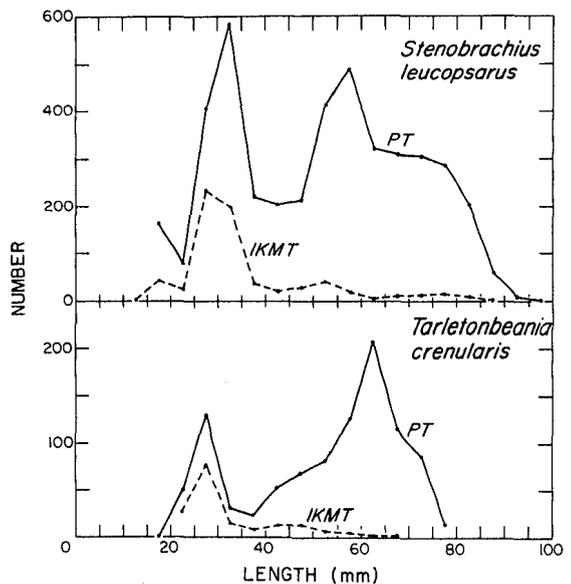


FIGURE 3.—Length-frequency distribution for *Stenobranchius leucopsarus* and *Tarletonbeania crenularis* in pelagic trawl and IKMT collections, July 1976, 0-500 m.

calculated from a flowmeter mounted in the MPS and monitored aboard ship via electrical cable (see Percy et al. 1977). Distances trawled by the pelagic trawl were calculated from ship speed (based on Loran readings) and the duration of the tow. In each comparison, tows and nets selected fished similar depths at the same time of day. The mouth area estimated in this way varied from 19 to 3,161 m<sup>2</sup> with a median value between 48 and 62 m<sup>2</sup> (Table 3). The smallest area (19 m<sup>2</sup>), for *D. theta*, can be largely explained by the retention of small fish (10-15 mm) in the IKMT but not by the slightly larger mesh of the pelagic trawl. This is the only obvious example of differences in size-frequency distributions that can be explained by escapement of small fish. The large values of mouth area may result from different population densities of two species at the times of sampling during the 1977 cruises.

The present study indicates that large nets usually catch more individuals, and usually, but not always, more species and larger animals than small IKMT-type nets. Detailed quantitative comparisons are needed with nets of known cross-sectional areas, with similar mesh size, at the same depths and locations (Roper 1977). Large nets will never replace the smaller IKMT's and rectangular midwater trawls because of the specialized equipment needed to launch and re-

TABLE 3.—Estimates of the effective mouth size of the pelagic trawl (PT) based on estimated distance trawled (speed × time), the catches of four lanternfishes, and the catches of four lanternfishes and volumes for IKMT's on "paired" cruises.

Item	<i>Stenobrachius leucopsarus</i>	<i>Diaphus theta</i>	<i>Tarletonbeania crenularis</i>	<i>Protomyctophum thompsoni</i>
1975—1 PT, 5 IKMT, 340-350 m, day:				
Distance trawled by PT = 23,718 m				
Vol. filtered by IKMT = 435,210 m <sup>3</sup>				
No. caught in PT	2,121	216	146	218
No. caught in IKMT	816	212	61	123
Effective mouth area, m <sup>2</sup>	48	19	44	32
1976—8 PT, 11 IKMT, 0-350 m, day/night:				
Distance trawled by PT = 148,425 m				
Vol. filtered by IKMT = 1,525,860 m <sup>3</sup>				
No. caught in PT	4,306	1,663	1,007	183
No. caught in IKMT	718	644	167	60
Effective mouth area, m <sup>2</sup>	62	27	62	31
1977—2 PT, 3 IKMT, 290-325 m, day/night:				
Distance trawled by PT = 18,931 m				
Vol. filtered by IKMT = 630,385 m <sup>3</sup>				
No. caught in PT	2,658	149	388	192
No. caught in IKMT	28	4	2	100
Effective mouth area, m <sup>2</sup>	3,161	1,240	646	64

cover large nets from oceanographic vessels. We need to compare catches of different-sized trawls, however, in order to evaluate biases and to learn what portions of the plankton-micronekton-nekton spectrum are effectively sampled by different nets.

#### Acknowledgments

This research was supported by the Office of Naval Research through Contract N00017-76-C-0067 under Project NR083-102. I am grateful to M. Willis, D. Stein, and R. Mesecar for comments on the manuscript, to J. Fisher, F. Evans, and D. Stein for invaluable help at sea, and to G. Loverich for design and evaluation of the pelagic trawl.

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